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Progress Report No. 4

INFRA·RED

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GLASSES FOR INFRARED REFRACTIVE SYSTEMS

INTRODUCTION: The rapidly increasing interest in Infrared Materials outlined in earlier Progress Reports has stimulated interest in the design of refractive systems in addition to filters and windows for use in this region of the spectrum. As a result we have completed the development of three additional glasses which are designated as Types 827250, 850324, and 915213. You may recognize these by designations initially given by the National Bureau of Standards as C-601, F-158 and A-2059, respectively.

Flint Glasses, such as the 915213 glass were first investigated before 1955 by the NBS, under Navy sponsorship (1), then, in 1956 processed in pilot operation for full scale production and specified for infrared properties by R. Weidel and associates (2) at Bausch & Lomb.

The 850324 glass was formulated at the National Bureau of Standards 3, under the same Navy sponsorship (1), and adapted for full scale production at Bausch & Lomb (2), together with the flint and calcium aluminate glasses.

(1) NOrd-03025

(2) N. J. Kreidl, R. A. Weidel and H. C. Hafner "Infrared Transmitting Glasses" JOSA 47 (6) 567-568 (1957)

(3) G. W. Cleek and E. H. Hamilton, J. Res. NBS 57 (6) 317-324 (1956)

Data on characteristics of interest to the designer are tabulated in the pages to follow. Explanations, where pertinent, appear under section headed "Descriptive Data".

FORM: These glasses may be classified in much the same manner as the optical glasses which are described in our regular Optical Glass Catalog. The material can be supplied either as molded blanks or as slabs in Grades B and C. Reheating and molding of the material requires somewhat more skill, but for anyone interested in this approach, more data can be supplied which is outside of the scope of this report.

SURFACING: Conventional optical surfacing techniques are used for all 3 types. Being high index glasses however, their thermal shock resistance is lower than conventional optical glasses and extra precautions need to be observed in this regard.

USE: These glasses are designed for refractive systems to be used in the near-infrared portion of the spectrum.

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OPTICAL PROPERTIES:

Refractive Index: Wavelength in Microns	Refractive Index 827250	850324	915213
0.4047	1.88915	1.89799	1.99761
0.4341	1.87201	1.88504	1.97437
0.4359	1.87109	1.88434	1.97314
0.4861	1.85089	1.86881	1.94609
0.5461	1.83509	1.85643	1.92553
0.5876	1.82727	1.85022	1.91541
0.5893	1.82700	1.85000	1.91500
0.6563	1.81781	1.84258	1.90313
1.0140	1.7960	1.8244	1.87599
1.1287	1.7927	1.8214	1.87201
1.3620	1.7877	1.8168	1.86617
1.5295	1.7849	1.8140	1.86309
1.6606	1.7828	1.8118	1.86084
1.8131	1.7807	1.8095	1.85849
1.9701	1.7784	1.8071	1.85615
2.1526	1.7757	1.8041	1.85359
2.2493	1.7744	1.8025	1.85218
2.3254	1.7732	1.8012	1.85102
2.4374	1.7715	1.7992	1.84926
2.577	1.7693	1.7967	1.84733

Melt to Melt Tolerance on Refractive Index	±.0025	±.0030	±.0035
Nominal n_D	1.827	1.850	1.915
Nominal V	25.0	32.4	21.3
Nominal Transmittance	Fig. 1	Fig. 2	Fig. 3
Annealing	Precision-fine-coarse-all types		

QUALITY: Striae — Grades B and C — all types

Bubbles

These glasses have been given the following bubble Codes:

Type	Bubble Code
827250	2
850324	4
915213	1

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PHYSICAL PROPERTIES (where available)

Property	Glass Type 827250	850324	915213
Density (Sp.Gr)	5.44	4.62	6.01
Tensile Strength (approx. lbs/sq. in)	X	X	5000
Young's Modulus (X 10^6 lbs/sq.in.)	X	X	7
Thermal Expansion Coefficient (X 10^{-7} cm/cm/^{o}C (Ave. 25^{o}C-300^{o}C)	91	83	98
Top Anneal temp.	750^{o}F	1350^{o}F	750^{o}F
Temperature glass withstands	570^{o}F	X	570^{o}F
Safety precautions	none	Contains Thorium	none

DURABILITY

	Glass Type 827250	850324	915213
Staining time in 1% HNO_3 at 25^{o}C	Immediately	100 hrs.	dissolves
Stain test class	5	1	5
Dimming test class	1	1	1

DESCRIPTIVE DATA

For your convenience in interpreting the tabular data a more detailed explanation follows:

REFRACTIVE INDEX AND TOLERANCE

The refractive indices shown in the tables are nominal values, the wavelengths for which are given in their respective headings.

To assure uniformity, and yet permit economical manufacture, it is necessary that tolerances be permitted. The extent of these tolerances is largely determined by the type of glass and is given in the table.

Glass which is supplied in precision or fine annealed form will be within this range. If glass is supplied in coarse annealed form, the index of refraction will be several units in the fourth place lower.

ANNEALING

All glass is annealed in one of three ways:

1. Precision Annealing – so that it will have high optical homogeneity. Glass annealed in this manner will be uniform in refractive index throughout any given piece within .00002 and have a birefringence equal to fine annealing.

   An extra charge is made for this grade of annealing.

2. Fine Annealing – so that the birefringence resulting from the permanent strain will produce a relative retardation or path difference of no more than 10 millimicrons for one centimeter of transmitted path of sodium light.

   No extra charge is made for this grade of annealing.

3. Coarse Annealing – so that the glass can be cut to size for future pressing without danger of chipping or shattering.

Pressings are supplied fine annealed unless it is specifically requested that precision annealing be done.

Slabs or plates can be annealed in any of the three methods defined above. If optical components are to be produced directly from material in this form, precision or fine annealing should be specified. If glass is to be molded to some desired shape, coarse annealing is sufficient.

Where desired, the schedule for fine annealing will be furnished.

Index sheets giving the index of refraction for the C, D and F lines can be provided when specifically requested on the order. Index sheets can be furnished in two classifications:

a. Approximate: These values are the results of annealing performed for control purposes and should be used for guidance only since variations might be expected among individual annealing runs, or where annealing is performed by others than ourselves. No extra charge is made for these data.

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b. Monitor: When glass is ordered in precision annealed form, the actual index values measured to an accuracy of ±.0001 from a monitor sample annealed in the same run can be supplied at time of delivery. In addition to the C, D and F lines index values for this grade of annealing will include the following spectral lines:

1.0140 Microns
1.5295
1.9701
2.4374

An extra charge is made for this service.

Striae:

Slight differences in index of refraction give rise to striae, which are visible to the naked eye under dark field illumination. Only occasionally are these striae sufficiently pronounced to permit their detection without special apparatus known as a striaescope. The effect of striae on optical performance is proportional to their density, quantity, and the location of the optical part. The prominence of striae tolerated varies inversely as their frequency. Since glass does vary considerably in its striae content, two grades are offered from which to choose, depending on the application:

Grade B - contains striae which are light and scattered when viewed through two opposite ends by means of a striaescope.

Grade C - contains striae which are light when viewed through two opposite ends in daylight with the naked eye. Striae will be approximately parallel to the surface of the plate, and will be invisible when examined through the faces with the unaided eye.

Bubbles:

Optical glass normally contains bubbles, the bubble content and the size of the bubbles varying somewhat with the different types. A bubble is defined as a gaseous inclusion no smaller than 0.02mm in average diameter. Such inclusions smaller than this size are not considered

visible. The most frequently occuring bubble in all types of glass listed is approximately 0.2mm or less in average diameter. Larger bubbles are present less frequently, but glass may have an occasional bubble with an average diameter as large as 0.5mm.

The following policy in regard to bubbles is followed in filling orders for optical glass:

Pressings - When glass is supplied in the form of pressings, bubble content will generally correspond to the bubble code identified with the glass type, unless special selection is called for on the order.

Plates or Slabs - When plates or slabs are supplied, it is assumed that selection for bubbles for any given application will be made by the consumer at the time of cutting the glass for the pressing operation.

The glasses listed in the table are classified for bubble content by a bubble code. This classification is an average only and is intended for guidance in the selection of a glass for a given purpose. Glasses whose averages fall between groups are classified in the nearest group, either higher or lower. Individual melts may be expected to show variation in bubble size and frequency from the values given. The code has the following translation:

Bubble Code	Average Number of Bubbles in 20cc
1	1
2	2
3	4
4	40

Temperature Glass Withstands

The values listed are those considered permissible in our filming operation for which the length of hold at the top temperature is not more than a few minutes. This is critical in that no significant change in the flatness of the polished optical surfaces can be tolerated.

Durability

Stain Test Class

The following table is used where the time is that to produce a 1/4 wavelength film:

Stain Test Class	Staining Time
1	100 hrs. in 1% HNO_2
2	10 to 100
3	1 to 10
4	0.1 to 1.0
5	Less than 0.1

Dimming Test Class

The following table is used where the appearance is that after a 28 day exposure at 100% humidity at 50°C:

Dimming Test Class	Appearance
1	no visible haze under room lighting
2	
3	intermediate between Classes 1 and 5
4	
5	haze to interfere with clear vision

AVAILABILITY: Type 827250 is produced in relatively small quantities amounting to approximately 80 cubic inches per melt. In types 850224 and 915213 can be melted in substantially larger volume.

Stocks are moderate and we are in good service position to supply moderate quantities of either pressings or slab material.

GENERAL DATA

Slabs and Pressings	Glass is supplied in random size squares or rectangles. No slab, however, is supplied with an area less than 4 square inches, nor is its length or width less than 2 inches.

The range of thicknesses extends from 5/16" as a minimum to 1-1/2" as a maximum and is to some extent dependent upon the type of glass. Pieces will vary no more than 1/8" in thickness from one to another within a specified melt.

Occasional chips may be present on the edges and corners. The size of these chips will not be in excess of 5% of the length of the edge having the chips. Slabs will have no vented fractures extending toward the center of the piece in excess of one centimeter in length. There will be no chill cracks deeper than one millimeter.

It is usually more economical in both labor and time to finish lens and prism elements from pressings approximating the dimensions of the finished part, especially if quantities of 100 or more of an individual size or shape are required, or if the piece is unusually large. A wide variety of molds is available, permitting desired sizes to be approximated closely. Special molds can be prepared where the need arises. Pressings are offered in Grades B and C glass.

When ordering pressings, allowances should be made for losses incurred in finishing. These losses will vary with the type of pressing and the manufacturing process which is used. When pressings are ordered for an element of given finished dimensions, allowance is made for the removal of 1-1/2mm from the clay surface, 1/2mm from the clear side, and 2mm from the diameter. All glass is inspected thoroughly for quality prior to pressing. All pressings are inspected 100% for glass type, annealing, and pressing defects. Defects within the area that is normally removed in finishing are not considered cause for rejection.

Quantities:

Orders which must be processed to specifications may be filled with an overage or shortage of from 5% to 10%, depending on the quantity and size specified. Although allowances are made for normal processing losses, the nature of the material makes this variation an economical procedure. Orders which must be filled without quantity variation shall be so specified.

Unless shipping instructions are given on the order, shipments are made by the most practicable method. Glass is packed by proven standards. Claims for damage in transit should be filed with the carrier at time of receipt. Please report promptly any shipments not received in due time.

HOW TO ORDER: So that your inquiry or order will receive prompt and careful attention please be sure that it includes:

1. quantity
2. type of glass
3. striae grade
4. annealing quality
5. type of index data
6. physical dimensions — specify whether finished or unfinished.

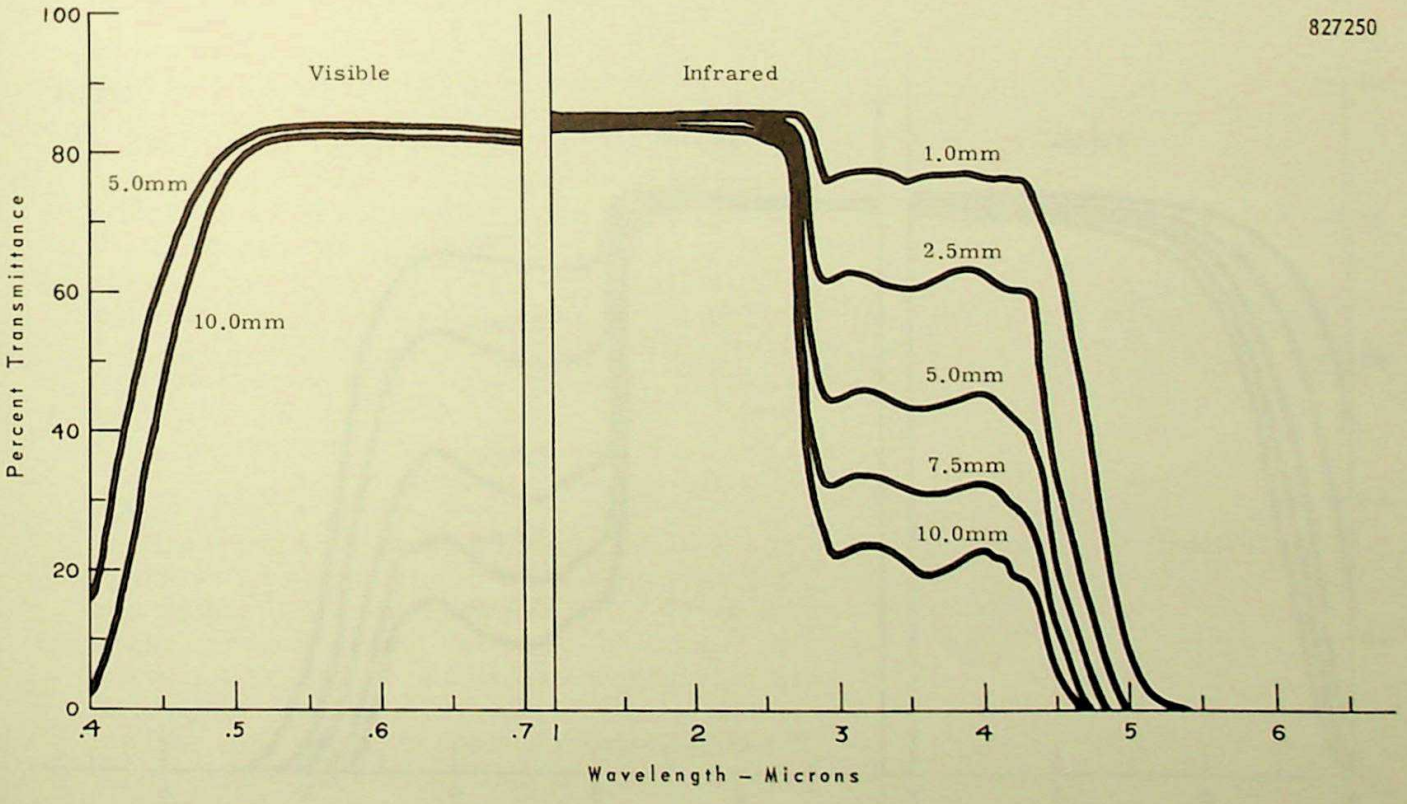

Fig. 1

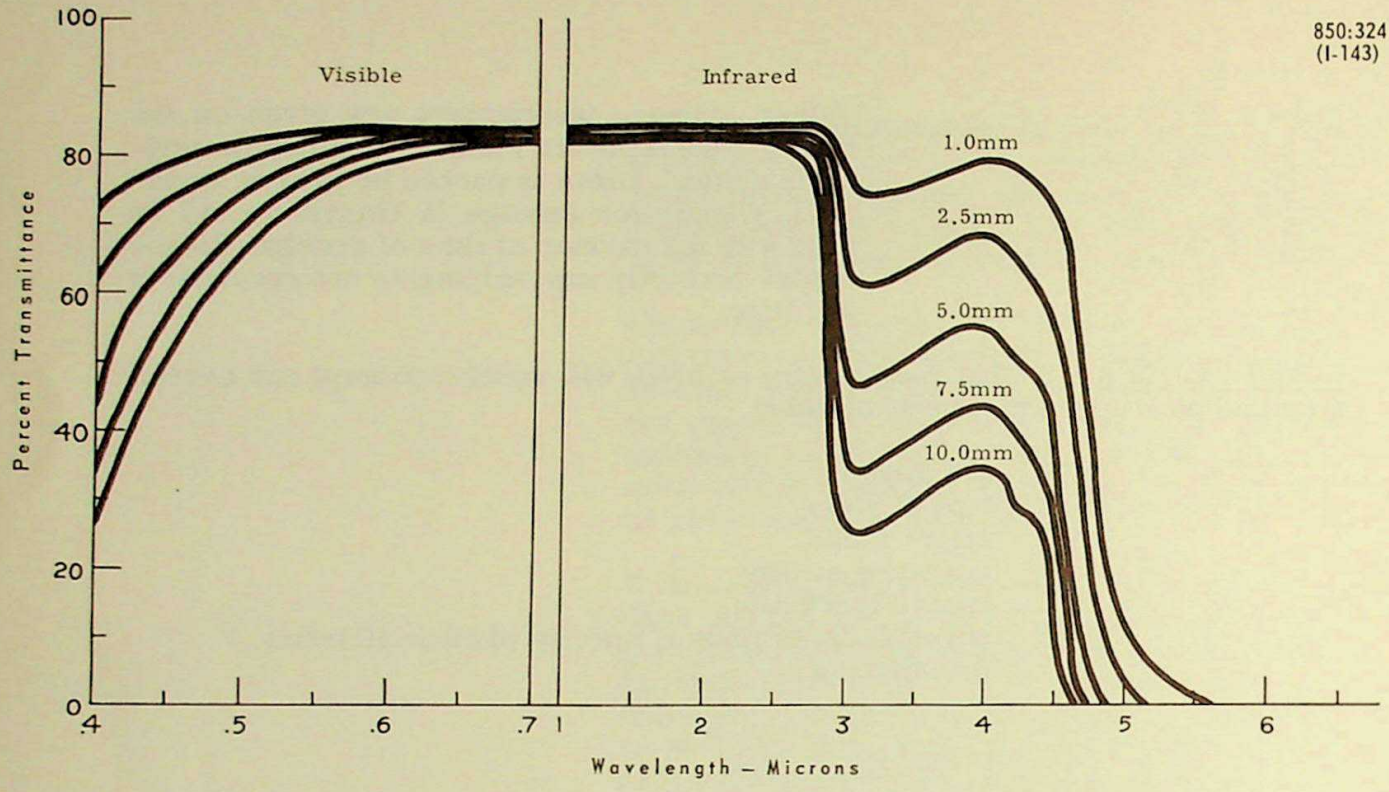
850:324
(I-143)
Visible
Infrared
1.0mm
2.5mm
5.0mm
7.5mm
10.0mm
Percent Transmittance
100
80
60
40
20
0
.4
.5
.6
.7
1
2
3
4
5
6
Wavelength – Microns

Fig. 2

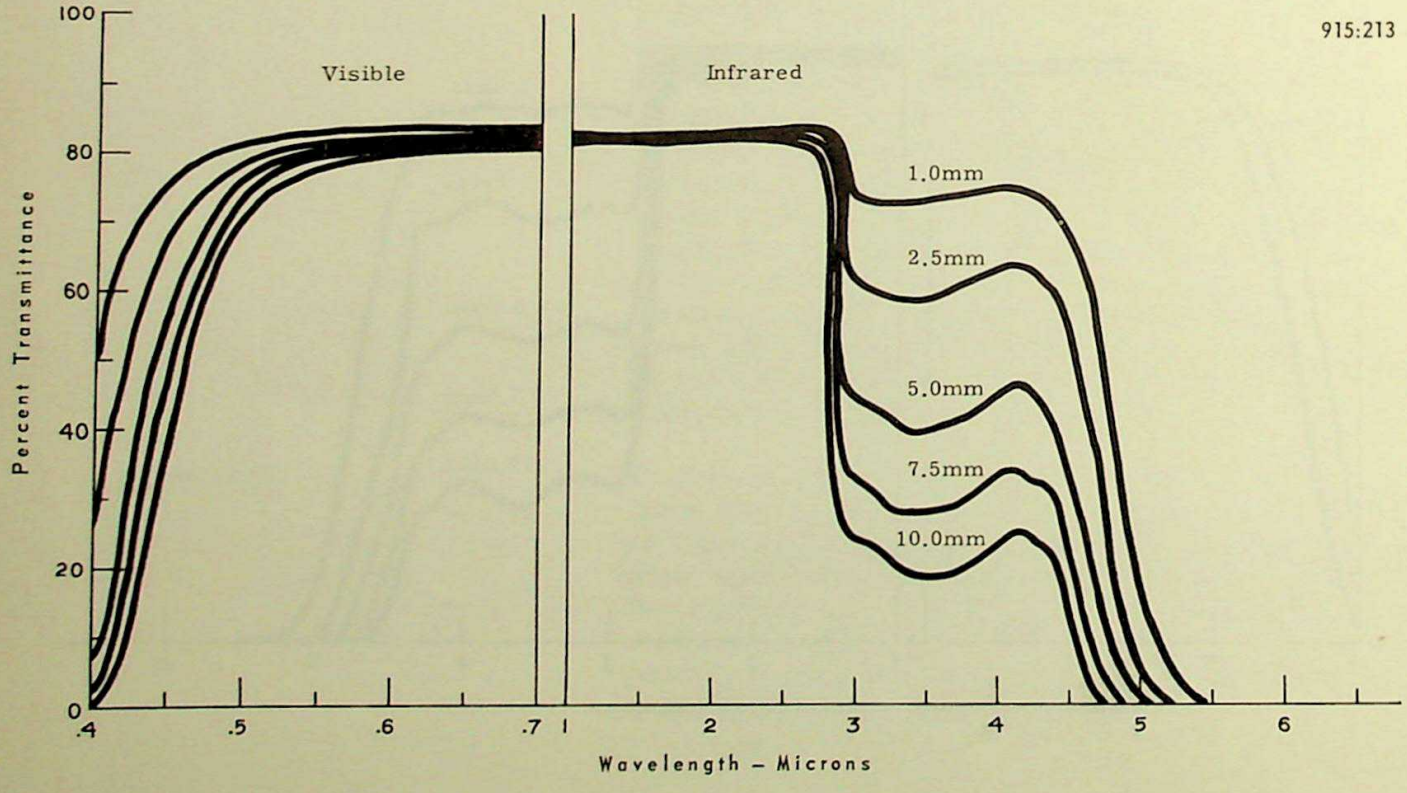
915:213
Visible
Infrared
1.0mm
2.5mm
5.0mm
7.5mm
10.0mm
Percent Transmittance
100
80
60
40
20
0
.4
.5
.6
.7
1
2
3
4
5
6
Wavelength – Microns

Fig. 3

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